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A multimodal and kinesiological approach to the development of negation in signing and non-signing children¹

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Abstract

This article applies Boutet’s kinesiological approach (2018) to a study of the expression of negation in four children evolving in contrastive language environments: predominantly monolingual (English, French, LSF) or bilingual (LSF-French), predominantly unimodal (visual modality- gestural) or bimodal (visuo-gestural and audio-vocal). We approach the expression of negation in its developmental and multimodal aspects according to an integrated model that views gestures as part of language. Our hypothesis was that some of the formal features of the gestural expression of negation are invariant and common to signing and non-signing children. In this study, we describe the emergence and development of multimodal expressions of negation, depending on whether the target language integrates sign language or not, and explore the gestural invariants of the expression of negation. We focus on two shared gestures present in the four children to determine their kinesiological invariants. We show how the four children studied in this paper produce shared gestures combined with the target languages in bimodal expressions of negation. In addition, the two signing children use forms of gestural negation which gradually become grammaticalized and integrated into sign language with age. We propose a common origin to what are usually called “co-verbal gestures” of negation, and the sign language-core lexicon of negation. Shared gestures and sign-specific gestures could be part of a continuum in which semantic and formal features are tightly connected, confirming that the body *informs* meaning.

Key Words

Bimodality, gesture, kinesiological approach, language acquisition, negation, sign language

Introduction

What has been characterized as a “cataclysmic break” (Singleton et al., 1995) and has governed some approaches to the relations between gestures and signs (Liddell & Metzger, 1998; Liddell, 2003; Goldin Meadow & Bren- tari, 2017) raises the question of what is *part of language*

or what is *partner to language* (Morgenstern & Goldin-Meadow, in press). Some authors are proponents of a progressive integration of gesture into sign languages through a grammaticalization process (Janzen and Shaffer, 2002; Wilcox, 2004); others demonstrate that there are gestural phenomena present alongside sign languages (Liddell, 2003), and others still view gesture participating

¹ This paper is adapted and enriched from Blondel et al. (2017). The Journal LIA gave the authors special permission to write an English adaptation of part of the paper to honor Boutet’s scientific approach.

in language defined in a broader sense, as claimed by McNeill (1992) or Kendon (2004)².

The kinesiological approach to gesture and sign (Boutet, 2018) considers gesture as an integral *part of language* and highlights possible continuities and invariants between gesture and sign through detailed analyses of their formal components associated with their semantic value in context. It can be applied to any semantic domain and all kinesic forms of expression. The focus on a particular semantic category in specific datasets makes it more feasible to analyze its gestural expressions in detail across gestures and signs. Negation is specifically propitious to this approach as it is deployed both in gestures and signs and as there is a common repertoire of gestures fully integrated in sign languages (Morgenstern, Blondel, Beaupoil-Hourdel et al., 2017). The aim of the present study is to indicate that dichotomies between gesture and sign are not as strong as some have claimed. In particular, the description of gestures as idiosyncratic and not decomposable, unlike signs, will be revisited with regards to gestural negation.

We approach the expression of negation in its developmental and multimodal aspects according to an integrated model of language that includes “preverbal categories, and takes into account gestures and other kinesic aspects of communication” (Benazzo & Morgenstern, 2014: 176). In this paper, we particularly focused on the visuo-gestural modality. By analyzing child developmental data, our aim was to demonstrate the presence and blossoming of recurrent features that characterize gestural negation across languages. Our hypothesis was that some of the formal features of the gestural expression of negation are invariant and common to signing and non-signing children. That does not mean that our approach supports the universality of gesture; mappings between gestural forms and meanings have been proven to be widely diverse across cultures and according to communicative practices in parallel to linguistic, cognitive or ideological diversity (Kita, 2009). As Darwin (1872) had already demonstrated in his overview of a large range of gestures of negation, there is “considerable diversity” (p. 277). But he also insists that there is “much uniformity” (p. 277) and a number of studies have shown how conventional gestures of negation can be widespread (Cooperrider, Abner, & Goldin-Meadow, 2018). Our approach enriches Darwin’s explanations according to which those similarities could be rooted in food avoidance or refusal in early infancy, and thus in the actional origin of certain gestures. More generally, the kinesiological approach (Boutet, 2018) illustrates how meaning is structured by the biomechanical constraints of the body, which are seldom taken into account in gesture studies. Gestures and signs can be considered as the result of the grammaticalization process grounded in the physiological affordances of human-beings’ actions and interactions over time.

During childhood and across the lifespan, negation can be expressed via different resources: linguistic signs, gestures, communicative actions, and various combinations

of these categories through audio-vocal and visuo-gestural modalities. We were therefore interested in all mono- and multi-modal utterances, including actions with communicative value in interaction, which enable signing and non-signing children to express opposition (“I am not the one supposed to do that”), refusal/rejection (“I don’t want to do this”), ignorance (“I don’t know”), denial (“that’s not what you mean”), non-existence (“there are no toys in the fridge”) or absence (“there are no more yogurts in the fridge”).

By comparing forms of negation and their function in children’s discourse - depending on whether or not they are exposed to sign language early on - it was possible to study the gesture-sign interface as it develops. Our collective team has published a series of papers in which we analyzed all expressions of negations in hearing monolingual children speaking French and English, a deaf child using LSF (French sign language) a bilingual child (French/Italian) and a bilingual bimodal child (French/LSF) (Benazzo & Morgenstern, 2014; Beaupoil-Hourdel, Boutet & Morgenstern, 2015; Morgenstern & Beaupoil, 2015; Morgenstern, Beaupoil-Hourdel, Blondel & Boutet, 2017; Morgenstern, Blondel, Beaupoil-Hourdel, Benazzo et al., 2017). The present paper is a synthesis of our findings and presents a focus on gestural forms of negation in multimodal French and LSF that illustrate the kinesiological approach in more detail.

The issue of the gesture-sign interface is linked to the question of the history of sign languages as well as that of the existence of gestures *shared* between the deaf and hearing communities. Zeshan (2006) in her work on the expression of negation across sign languages and in the emerging forms used by isolated deaf people (or home-signs), has highlighted how much the connections between signs and gestures are important. Indeed, the many lexical and morphosyntactic forms involved in the variety of sign languages she studied are closely related to the gestures of the speakers of the surrounding spoken languages (Armstrong, Stokoe & Wilcox, 1995). Negation is therefore of great interest for a typological approach across languages and modalities as it offers a privileged perspective to observe the links between different sign languages on the one hand, and between symbolic gestures that belong or do not belong to the sign language core lexicon, on the other hand.

A parallel can be drawn between the institutionalization of sign languages and the grammaticalization of gestures in children’s communicative development, that is to say between the evolution of gestures within a linguistic system in the history of a sign language and their development in children’s language. We will illustrate how forms do not replace each other over time - both in the history of sign languages and in children’s language development. Some gestures persist in stabilized languages, whether they are spoken or signed. Independent lexical signs also persist alongside grammatical morphemes in the linguistic systems of sign languages.

² But see Müller (2018) for a thorough analysis.

The present study is grounded in a review of the literature concerning the expression of negation in relation to gesture both in acquisition and in comparisons between sign languages. We show how a kinesiological approach to gestures allows us to bring out gestural patterns that present a contrast at the semantic level. We then compare four profiles of young children - LSF, English, French, and LSF-French—in order to uncover both individual features (specific to each modality and language) and invariant features (across modalities and languages) of multimodal negation and its development. Among the various forms observed, we will focus on two gestural patterns: the so-called “Palm-Up” gesture (studied in detail by Beaupoil-Hourdel and Debras, 2017; Beaupoil-Hourdel and Morgenstern, in press) and the Index-Wagging gesture, common to the language repertoires of the four children. We hypothesize that the frequency and distribution of these two gestural patterns illustrate the variable features of the children’s input and that the two gestural patterns highlight the presence of formal gestural invariants uncovered by our kinesiological approach.

Gestures expressing negation

Different articulators are deployed in gestural productions including the chest, the arms, the hands, the head, the lips as well as the eyebrows. These articulators have had a different linguistic status depending on the categorizations used in the literature. The headshake is a case in point. All French, Italian, British or American children, whether deaf or hearing, shake their heads to mean ‘no’ while they are still very young. A great number of gestures expressing negation are used very early on in interactions with young children, whether the input is in a sign language or a spoken language accompanied by ‘co-verbal’ gestures. But among signers, “headshakes not only are communicative, but also function as a required component of the grammatical signal for negation” as explained by Anderson and Reilly (1998: 411). In order to take these crucial aspects into account, we will first present studies that deal with children’s gestures of negation, depending on whether or not they are exposed to a sign language; we will then focus on the expression of negation in adult signers; and finally, more broadly, on the expression of negation in human gesture.

Children’s gestures of negation

We will review the existing research by starting from the less systematized gestural context to the most grammaticalized context, considering the sign languages of isolated signers (homesign) as an intermediate context. Although we are particularly interested in gestures performed with the upper limbs, we account for the fact that negation can be expressed via all segments of the upper part of our body including the face, the head and the chest.

Non-signing children

Even if a number of authors emphasize the existence of inter-individual variations, they observe that head movements expressing negation (along with pointing gestures) are part of children’s first symbolic gestures and are the most frequent gestures used by young children (Andr en, 2010; Guidetti, 2005). Benazzo and Morgenstern (2014) analyze the productions of negation in a bilingual French-Italian child, Antoine, (without exposure to a sign language) and note that spoken occurrences become more numerous than gestural occurrences around the age of 2;6, after a transition phase during which the child produces a majority of bimodal utterances. Antoine uses a greater proportion of gestures for a longer period of time than the other children video-recorded in the framework of the *Paris Corpus* (Morgenstern & Parris e, 2012) or in Guidetti (2005) who analyzed the expression of refusal in thirty French hearing children at 1;4, 2;0 and 3;0.

However, all of the authors cited agree that the gestural modality does not disappear from the expression of negation, but helps reinforce or replace spoken messages when necessary. The idea according to which speech replaces gesture is linked to a period qualified as the “dark age” by McNeill (2014), which corresponds to the relative disappearance of gestures between 2 and 3 years old in hearing monolingual children, when they are most focused on the acquisition of speech.

Isolated child signers

Homesign is a gestural system used by isolated deaf children without exposure to a stabilized sign language (Cartmill et al., 2017; Fusellier, 2001; Goldin-Meadow & Mylander, 1998). This acquisition context therefore constitutes a sort of missing link between signing and non-signing children.

David is a deaf American child of hearing parents who has not been exposed to any conventional sign language (ASL in this case). Franklin, Giannakidou, and Goldin-Meadow (2011) have analyzed his productions between 2;10 and 3;11, focusing on interrogative and negative structures³. The authors have a more logical-formal approach to negation than ours. They consider that negation is defined as a sentential modification. This logical modification in homesign includes both “lexical items” which function as negation markers, and head movements, which the authors consider as negation operators. According to their observations, “79% of the headshakes David produced in multi-gesture sentence appeared at the beginning of the sentence” (p. 401) thus constituting fundamental elements of children’s first syntax. Example (1) illustrates a negative construction in David’s productions at 3;11 when he performs “a side-to-side headshake, points at the guitar, and produces a PUT ON gesture

3 Remarkably, Franklin et al. (2011: 399) remind us that in many languages negation and interrogation operators share morphological resources.

[O-hand moved down in the direction of the soldier], followed by a point at soldier” (p. 401).

- (1) Headshake Pointing > *guitar* PUT-ON_{gesture} > *toy soldier* Pointing > *toy soldier*
 ‘the guitar should not be put on the toy soldier’

The authors consider these structures as “de novo” language creations, but we hypothesize that they are mostly an excellent example of the integration of a negative gesture shared within the child’s community into his linguistic system (on the scale of this child’s environment). The interface between gesture and sign, which in this case is instantiated in what is called in the literature a “non-manual” form⁴ (a headshake), will be explored further on in our study by focusing on two “manual” patterns performed with the upper limbs (Index-Wagging and Palm Up).

Signing children

Anderson and Reilly (1998) note that the first studies mentioning the acquisition of negation in ASL (Ellenberg, Moores, & Hoffmeister, 1975, in particular) focused on the use of manual signs (whether they are lexical or grammatical). The authors are interested in the non-manual dimension of negation, and in the co-articulation of manual with non-manual components. In particular, they analyze the developmental relationship between headshakes with communicative value and headshakes with grammatical (or linguistic) value, in the expression of negation (p. 411). Echoing the eclipse mentioned by McNeill (2014), their study shows that children do indeed produce communicative headshakes around 1 year old, but that when they enter ASL grammar, they are not in a position to directly integrate the use of this communicative gesture into their emerging grammatical system. In other words, children seem to first acquire the manual NOT sign before they are able to produce the associated grammatical headshake. According to these authors, the following pattern emerges: when children first acquire a new negative manual sign, it is produced without the non-manual component, then the mandatory non-manual component is added to the manual sign a month to eight months later.

In summary, gestures and signs of negation are linked in acquisition. The grammaticalization of gestural units seems to be developed dynamically with possible stages of attrition. To better understand this link between the productions of signing and non-signing children, we will

turn to the adult target language before extending our discussion to the broader domain of human gestures.

Negation in sign languages (input)

Zeshan (2006) presents a cross-linguistic collection of negative and interrogative structures in 37 sign languages, most of which have a common negative elicitation protocol. This inventory is completed by a series of studies concerning each sign language separately (ASL, British sign language or BSL, Swedish sign language or SSL, Chinese sign language or CSL, Quebec sign language or LSQ).

Manual and non-manual categories of negation

On the basis of this research, the inventory of linguistic forms of negation that we present here includes gestural expressions, such as certain facial expressions, which can function as discourse markers or affective markers, for signers as well as non-signers (Anderson & Reilly, 1998: 412). Whether they are manual or non-manual, what we will call *shared gestures* are not distinguished from linguistic signs because of form-based differences but because of their grammatical role in the utterance, as noted by McNeill (2014: 154).

The criteria to distinguish affective and grammatical facial expressions are discussed in the literature. Baker-Shenk (1983) notes that there is an abrupt onset and ending to facial movements when they function as grammatical markers while the onset and ending of facial movements are articulated more gradually to express affective functions. The more or less adjusted synchronization of non-manual with manual movements is a criterion mentioned for phenomena other than headshakes - which interest us particularly here. This raises the issue of the objective measurement of the fine synchronization between non-manual and manual articulators. Furthermore, the studies mentioned do not report having measured synchronization between facial movements and vocal productions for non-signing populations, which could be particularly interesting as well.

Depending on the authors, and according to the forms under study, shared gestural forms are thus either integrated in the inventory of sign language itself, or considered as para-linguistic - on the fringes of language. To better account for the variety of possible combinations, we propose to classify the forms of negation according to the following distinctions: manual vs non-manual; forms common to signers and non-signers vs. forms specific to signers; independent forms vs linked forms (Table 1).

⁴ Boutet criticized how gesture studies were too much focused on the movements of the hand (2018). Instead of using *manual* and *non-manual* gesture, he described gestures as *deployed* (or *not deployed*) *on the upper limbs*, which include shoulder, arm, forearm, hand and fingers. As there is no shared terminology that takes this criticism into account (such as, for example, the use of the word *brachial*, but which is also underdetermined), we will continue using the terms *manual* and *non-manual* throughout this paper and hope the scientific community will come up with terms that refer to the upper limb as a whole rather than focusing on the hand.

Table 1. Categorization of gestural forms of negation.

Manual	Specific to SL	Negation signs: independent lexical forms	
			Morphological derivation: added hand movement to express negation (wrist rotation, or reverse movement in CSL, ASL or LSF, LOVE / NOT-LOVE ⁵ paradigm), negative handshake (little finger versus outstretched thumb) (in CSL), lateral versus vertical shaking of the hand (in CSL)
	Combined	Signs combined with ‘negative’ shaking of the hand	
	Shared	Index- or hand- wagging (in CSL)	
		Hand opening with Palm-Up	
Non-manual	Shared	Headshake (with or without the manual sign)	
		Shrugs	

* By convention, lexical signs are noted in the form of an *id(entification)-gloss* in upper case. Here LOVE designates the ASL sign that we could translate in English as ‘love’. We use ID-glosses in English in this paper, even when we refer to lexical signs that are originally in French sign language or other sign languages.

Unity and diversity of sign languages

Regarding the sequential organization of negation markers, Perniss, Pfau, and Steinbach (2007: 17) observe that interesting differences between sign languages have been noted in connection with the position of manual signs in the sentence and the co-occurrence of manual and non-manual elements. However, according to Anderson and Reilly (1998: 413) the discussion on the order of the constituents used in negation has not given rise to a fruitful comparison since sign order is relatively flexible: “a negative lexical manual sign can actually occur in a variety of positions within a sentence”.

Yang and Fisher (2002) show that certain aspects of negation in CSL are common to other sign languages⁵ (non-manual markers, the presence of negative lexical signs and negative sentence structures) but that other features are specific to CSL. One of these characteristic features is a manual negation pattern, the articulatory equivalent of manually signing the letter I in ASL.

Finally, regarding the impact of shared gestures on sign languages, Perniss et al. (2007: 18) indicate that some sign languages also use a backward movement of the head to express negation, and that this is the grammaticalization of a culture-specific gesture. In addition, pertaining to gestures that are of particular interest for the present study, Capirci, Iverson, Pizzuto, and Volterra (1996: 654) suggested that Index-Wagging is more culturally marked (specific to a gestural convention in a given culture) than Headshakes or Palm-Ups (which are more widely spread across communities).

Despite this rich linguistic and cultural diversity, systematic features in the gesture-sign interface can be uncovered. We will show in the following sections that gestures of negation can be modeled on the basis of their kinesiological characteristics and that common patterns can be retrieved through the comparative study of

forms of negation in several sign languages as well as in non-signing people’s gestures (Boutet, 2015).

Gestures of negation

Kendon (2004) and Calbris (1990, 2011) present very similar typologies of gestures expressing negation divided into two families depending on whether the palm of the hand is in pronation (Open Hand Prone, now OHP) or in supination (Open Hand Supine, now OHS). This distinction is often referred to in the literature as Palm-Down and Palm-Up (Bressem, 2013; Bressem & Müller, 2014; Stokoe, 2005 [1960]), and these two families can be broken down into several sub-groups.

Gesture families according to their frames of reference

OHP gestures can be performed in a vertical plane or in an oblique or horizontal plane, with or without a lateral movement. In adults (see authors mentioned above), but also in children (Darwin, 1872; Beaupoil-Hourdel, Boutet & Morgenstern, 2015), OHP gestures with the palm oriented vertically are interpreted as an interruption, a suspension, the stopping of a line of action, or even a denial, while OHP gestures with an oblique or horizontal orientation are clearly associated with notions of sweeping, cutting, which are visibly more descriptive than actional (Harrison, 2018).

Within the second family (OHS), the group of gestures presenting a lateral movement seems to be associated either with the expression of an inability to intervene in a situation, with the observation of the obvious, with a rhetorical question calling for no response, with potential existence, or finally, with an invitation made to someone (Debras, 2013; 2017; Kendon, 2004; Streeck, 1994). All these associations are based on a withdrawal from the situation and are the expression of the non-intervention of the speaker. This gesture family is often associated with shrugs (Bressem & Müller, 2014; Debras, 2013; Streeck, 2009).

As shown in Morgenstern, Chevrefils, Blondel, et al. (this issue), the group of OHS without this lateral movement is often interpreted as presentation gestures. The description of gestures via this categorization into families has so far been part of an ego-centered frame of reference. This describes the situation in which gestures are analyzed in relation to the person who produces them rather than for themselves. The description focuses on the orientation of the most distal segment - the hand. To analyze gestures for themselves, we need to describe the position of each segment (fingers, hand, forearm, arm, shoulder) and the movement of each segment in its own field of

5 Their study is based on references to American, British, Swedish, Dutch and German Sign Languages (ASL, BSL, SSL, NGT, DGS, respectively).

possibilities, that is to say - within each degree of freedom (Boutet, 2015). Therefore, the frame of reference is intrinsic to each segment (Levinson, 1996) and multiple. There are as many references as there are degrees of freedom (Boutet, 2008). This approach can help us determine the formal invariants of gestural negation: each degree of freedom can individually be a negation carrier.

Degrees of freedom and propagation of the movement

As explained in Morgenstern, Chevrefils, Blondel, et al. (this issue), a degree of freedom is the movement of a segment around an axis. This axis can be perpendicular to a segment or can run along the axis of the segment (along the arm, along the forearm).

In full pronation (OHP), the hand can be oriented downward, or forward when the forearm is fully flexed, or it can even be oriented inward when the forearm is fully flexed and the elbow is projected forward (Figure 1). We can clearly see here that a series of different orientations (downward, forward or inward) according to an *egocentric* frame of reference can correspond to the same position of the hand according to an *intrinsic* frame of reference.

These degrees of freedom are sometimes set in motion simultaneously, but more often consecutively along the upper limb. The gestures are therefore deployed according to a proximal-distal flow (from the closest to the chest towards the farthest on the upper limb) or a distal-proximal flow.

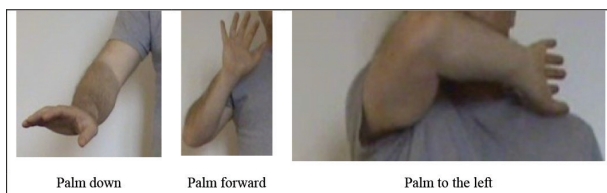


Figure 1. Pronation and ego-centered reference.

The direction of the movement has an impact on the meaning of the gesture (Boutet, 2001). Thus when the hand is in full pronation (palm downwards), if there is an extension of the hand and fingers in a proximal-distal flow – the extension of the wrist is followed by the first phalanges, then the intermediate and finally the last phalanges – the meaning of the gesture is akin to distancing. If the movement is distal-proximal – it first affects the last phalanges then the intermediate phalanges and finally the proximal phalanges before the extension of the wrist – the meaning is refusal (Calbris & Montredon, 1986; Boutet, 2001). Thus in the OHS family, (see Morgenstern, Chevrefils, Blondel, et al., this issue), flow differentiates presentation gestures from gestures of withdrawal. Kendon (2004) considers that presentation gestures are mostly performed with one hand, while gestures of withdrawal are mostly bimanual with a lat-

eral movement. But these trends based on static analyses of the function of segments are not systematic and do not prevail when faced with the reality of the data (Harrison, 2010; Debras, 2013). It would be more accurate to differentiate gestures according to movement and flow: the flow of presentation gestures is distal-proximal while the flow of withdrawal gestures is mostly proximal-distal. According to Boutet (2010), flow constitutes a ‘phonological’ feature that makes it possible to distinguish minimal pairs. We will thus identify and distinguish the gestural patterns of negation based on these kinesiological descriptions.

Segmental origin and movement transfer

In the kinesiological approach to gestural forms, we need to describe movement and how it circulates between segments. From the arm all the way down to the fingers, there happens to be a decreasing gradient of inertia. It is easier to move a segment with a lower mass when the movement propagates from a segment with a higher mass than the other way around.

According to Dumas et al. (2007), the forearm represents 65% of the inertia of the arm on average and the hand 24%. The abduction and adduction of the hand represent the smallest amplitude of the upper limb: 35° and 45°. The joint stop is therefore reached quite quickly and transfer of the forearm is possible despite the difference in inertia. The movement is then transferred to the forearm; it does not go much further (it does not propagate onto the arm). The other manual degree of freedom whose movement is transferable to the forearm is flexion/extension. But the amplitude of this degree of freedom is much greater: 90° for each pole. Note that these two manual degrees of freedom are perpendicular to each other, so that when one of them transfers its movement to the flexion/extension of the forearm, the other diffuses its movement to the interior/exterior rotation. In contrast, pronation/supination, which is a manual degree of freedom that runs along the forearm, has no impact (in terms of inertial transfer) on the inner/outer rotation or flexion/extension of the forearm.

The manual segmental origin radiates on both sides of the hand - onto the fingers and the forearm. The same meaning can therefore be expressed via one segment or the other. For example, a gesture of negation performed with lateral oscillations of the index finger pointing upwards has the same meaning as a lateral swinging gesture of the forearm with the hand in a frontal plane and all fingers pointing upwards. Figure 2 presents two examples of negation in two sign languages and a gesture accompanying a grammatical negation in French (“ne... .pas”) in a hearing-speaking child, Madeleine, at the age of 4;1. This illustrates that the number of extended fingers, the movement of the hand or the forearm correspond in fact to variants, both in sign languages and in hearing speakers’ gestures.

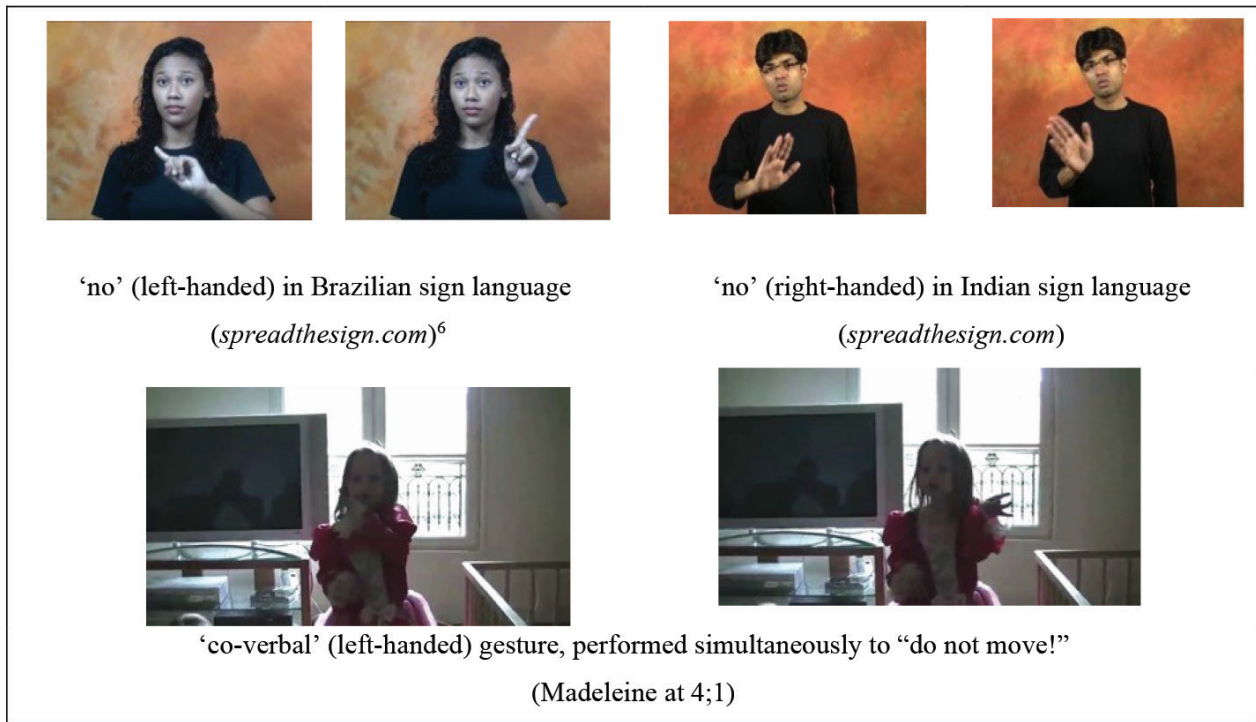


Figure 2. Lateral scanning movement in a frontal plane from the inside to the outside.

In our kinesiological approach, we clearly distinguish segments that *are set in motion* (displacement) and segments that *move*. The displacement of a segment is the result of a movement initiated on a more proximal segment. A segment *set in motion* does not create meaning, but diffuses it by prolonging the overall movement. For example, in a gesture representing a barrier through vertical palms facing forward with fingers pointing upwards and with a lateral and symmetrical homogeneous movement of the forearms spreading away from each other at constant speed, the hands are in *motion*. The orientation of the hands and the lateral movement of the forearms *inform* the meaning of the gesture. But the *motion* of the hands does not contribute to the meaning of the gesture (they might only intensify the meaning). Only the forearms are the actual *motor* of the movement.

Movement transfer implies that the movement of at least one degree of freedom of the segment considered is due to the movement of at least one degree of freedom of a more proximal or more distal segment; movement transfer projects the meaning of the gesture onto the affected segment. The gesture of refusal deployed on the hand and forearm (Figure 3) seems quite similar to the

barrier gesture we have just presented. However, the lateral movement of the hand here is not due to the movement of the forearm. On the contrary, the maximal adduction position of the hand, which reaches an articular stop, causes the outward rotation of the forearm. The meaning of the gesture derives from the position of the hand, the movement of adduction, pronation and extension of the hand, and the lateral movement of the forearm. The movement transfer of the hand, which affects the forearm, thus contributes to the meaning of the gesture: refusal.

What we have illustrated here through different gestures (*barrier* and *refusal*) in the same OHP family also applies to gestures in the OHS family: *presentation* and *withdrawal* gestures (Figure 4).

This general presentation of the kinesiological approach to gestural negation allows us to account for the gestural production of children who express themselves in different languages and in different modalities. In the following section, we present the data and method. We focus on the systematic patterns and gestural properties that are at play in the expression of negation and in particular on the form-meaning interface of the two contrasting patterns that we have just presented: Palm-Up and Index-Wagging gestures.

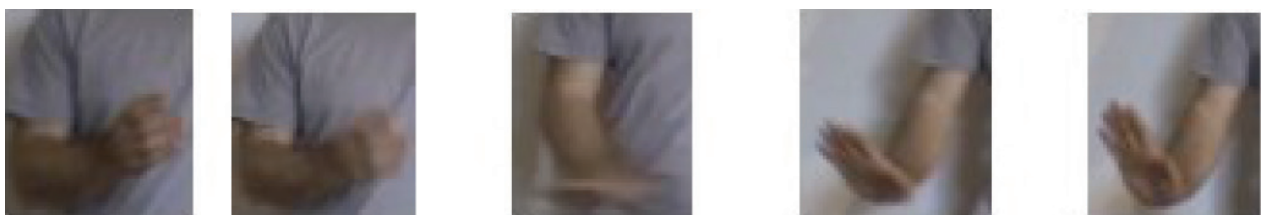


Figure 3. Decomposition of a refusal gesture.

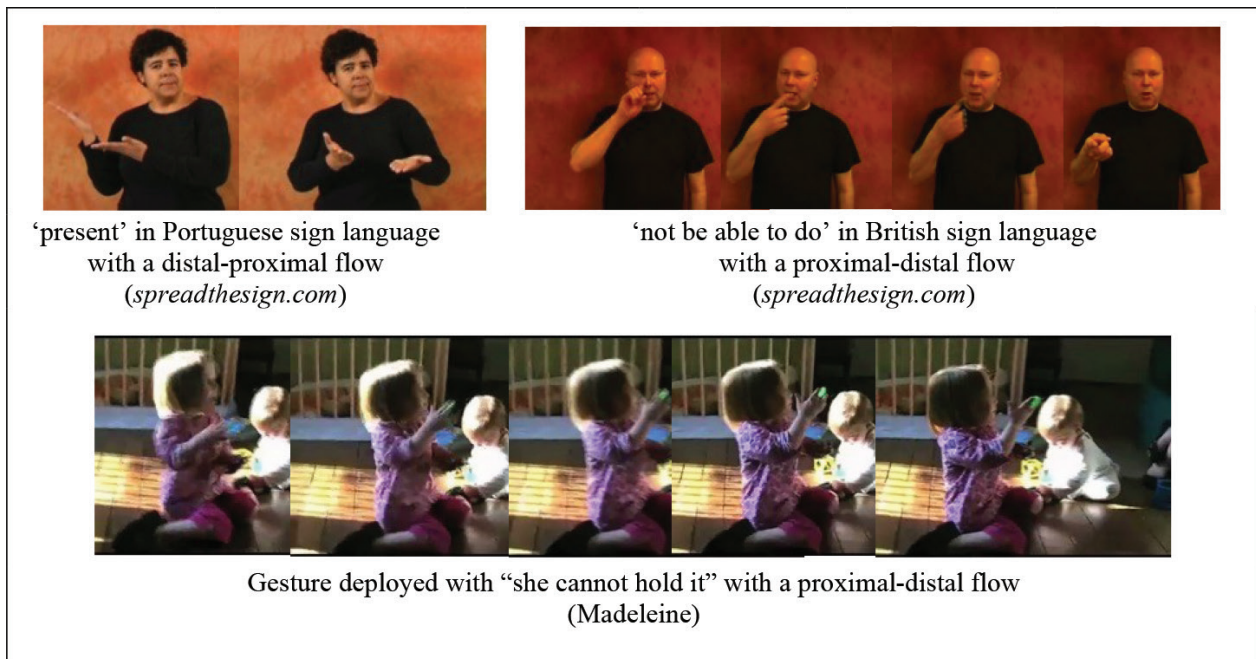


Figure 4. Contrastive flow between presentation and withdrawal gestures.

Data and method

In order to tackle variations and invariants in the development of the gestural expression of negation, we have collected longitudinal data in the families of two children exposed to LSF and two children with monolingual input (French or English). All four children were recorded at home, in the context of spontaneous interactions with their parents.

Data

Charlotte is a deaf child with deaf parents who use LSF. She is considered here as unimodal monolingual, even if this monolingual status is questionable from a sociolinguistic point of view as she lives in Paris and is surrounded by spoken and written French. The data was recorded by a deaf native signer (Limousin, 2011). Charlotte benefits from an essentially visuo-gestural input, ranging from actional gestures to linguistic signs, but she also has access to labializations resulting from contact with the surrounding spoken language, through lip reading (Millet et al., 2016). Among the monthly recordings, all forms of negation were coded in the sessions corresponding to ages 12 months, 18 months, 24 months, 27 months, 30 months, and 36 months.

Illana is a hearing child and is bilingual bimodal LSF-French, as her father is a deaf signer, her mother is bilingual bimodal and hearing. Illana was recorded by three hearing people who signed with the deaf parent in the same

way as they did outside this study, therefore in line with the child's usual environment, which was mainly hearing (Tuller et al., 2007; Blondel, 2009). The child benefitted from the full range of visuo-gestural and audio-vocal modalities, from actions and vocalizations to linguistic signs. The sessions used for this study that best matched Charlotte's were the sessions corresponding to ages 13 months, 19 months, 22 months, 26 months, 31 months, 35 months⁶.

Ellie is a British monolingual hearing child whose family speaks English. She was filmed by her grandmother as part of the *ANR CoLaJE* project (<https://chilides.talkbank.org/access/Eng-UK/Sekali.html>). All the sessions of the video corpus were annotated as part of a doctoral dissertation conducted within the project on the expression of negation (Beaupeil-Hourdel, 2015).

Madeleine is a monolingual hearing child whose family speaks French. She was filmed in the context of the *ANR Léonard* and *CoLaJE* projects by Martine Sekali (Morgenstern & Parrisé, 2012). Sessions 0;10 to 4;2 were also annotated as part of the same doctoral thesis on the expression of negation (Beaupeil-Hourdel, 2015).

Coding

We identified all forms of negation with annotation software used in the communities working on acquisition, gesture and sign languages: CLAN (MacWhinney, 2000) for Ellie and Madeleine, and ELAN (Sloetjes & Wittenburg, 2008) for Charlotte and Illana. Then, we transferred the coded data into a spreadsheet to classify the

⁶ The two longitudinal studies were not conducted at the same time and are subject to the family organization hazards of the video-recorded family; this explains the slight differences between the children's ages in the video-recorded sessions.

occurrences according to modality, formal category and function of the negative form in relation to its value in the interactional context and the situation. Finally, we finely described the kinesiological characteristics of sequences containing shared gestures, by targeting the contrastive patterns mentioned above.

All the manual and non-manual activity produced by the four children in the context of negation was described and classified. We used the four categories presented in Table 2 to assess the proportion of negative items according to languages and modalities.

Table 2. Basic categories.

Vocal Symbolic	Vocal non Symbolic	Gestural Symbolic	Action (non symbolic bodily movement)
"non" 'no'	Shouting, grunting	NONE (LSF), Index-wagging, Headshake	Action of pushing away (with contact on object)

The *Vocal non Symbolic* category was not sufficiently relevant for this study, whereas we needed to divide the *Gestural Symbolic* category into *Specific to LSF* and *Shared Gesture* (Table 3). The category *Specific to LSF* refers to the LSF lexicon and excludes signs which are also coverbal gestures that non-signing people can use; for example LSF NO⁷ (Figure 5) versus Index-Wagging. Both gestures mean 'no/not' but the first item is only found in a signer's utterance while the second is found as much in LSF utterances as in a non-signer's gestures. This distinction is used by other authors, such as Emmorey et al. (2008) to measure the proportion of (what they called) *gestures/signs* in the productions of bimodal bilingual speakers.

Table 3. Sub-categorization of symbolic gestures.

Specific to LSF	(Shared) Gesture
	Index-Wagging
NO	Headshake
NONE	Palm-Up
NOT-WANT	Shrug
NOT-LOVE	Wrinkled nose
	Frown (with eyebrows)
	Mouth movement (pouting)

We have therefore retained four main types of negation forms:

- (Sign specific to) *LSF*: Charlotte uses the sign NONE when interacting with her mother with whom she plays the merchant. We do not find this gesture (this sign) in the production of a non-signer and it is therefore what we call an *LSF* negation.
- *French / English*: Illana replies "nan c'est à moi" ('no it's mine'), with a variant of "non" ("nan"). This is what we call a *French* negation (for Illana and Madeleine, with the English equivalent for Ellie).
- *Shared Gesture*: When the little girl is 1;5, Ellie's grandmother asks her where her basket is and El-

lie responds with a Palm-Up-Open-Hand gesture (OHS, as described in section 2.3.1). This is what we call a *Shared Gesture* of negation.

- *Action*: Illana pushes away a glass of milk to signify that she does not want it.

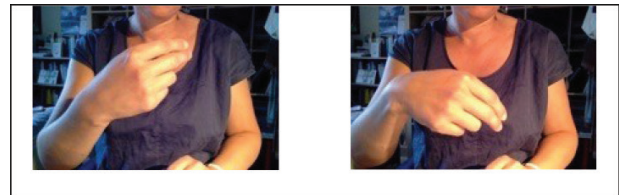


Figure 5. NON/NO 'no' in LSF.

Results: specific and invariant features

Our coding system allowed us to account for the children's varied pathways, depending on the degree of bimodality and the bilingual nature of the family environment. We also examined the common features which could attest to the same evolution towards a grammaticalization of the expression of negation. We identified invariants in the two contrasting gestural patterns we had selected to focus on: Palm-Up (or OHS) and Shoulder Shrugs versus Index-Wagging. In our final section, we highlight systematic links between dynamic kinesiological features and semantic features found in our interactive data.

Environmental and bimodal impact on the four children's gestures of negation

Visuo-gestural production includes actions and symbolic gestures. Figure 6 shows that the proportion of the visuo-gestural production associated with negation decreases for Ellie or Madeleine when they enter the verbal-vocal dimension.

Charlotte's productions are entirely visuo-gestural and the proportion of visuo-gestural productions for Illana (in light gray) is greater than for Ellie and less important than for Charlotte. In sessions 1;10 and 2;11, Illana is almost exclusively in interaction with her mother, which explains the high proportion of non-visual forms in the graph. In the other four sessions she speaks to both her parents and the visuo-gestural forms do not decrease in favor of vocal forms (contrary to what Benazzo & Morgenstern, 2014 note in a unimodal bilingual child), since Illana continues to use Headshakes, Index-Wagging and other forms of Shared Gestures. She seems to continually take into account the importance of giving visual communication cues, including through exaggerated labialization. The presence or absence of her deaf parent in the interactions clearly influences the proportion of her visuo-gestural production (in sessions at ages 1;10 and 2;11, the interactions are mainly with her hearing parent).

⁷ For convenience, we translated all the -Glosses into English, even when they were from different sign languages.

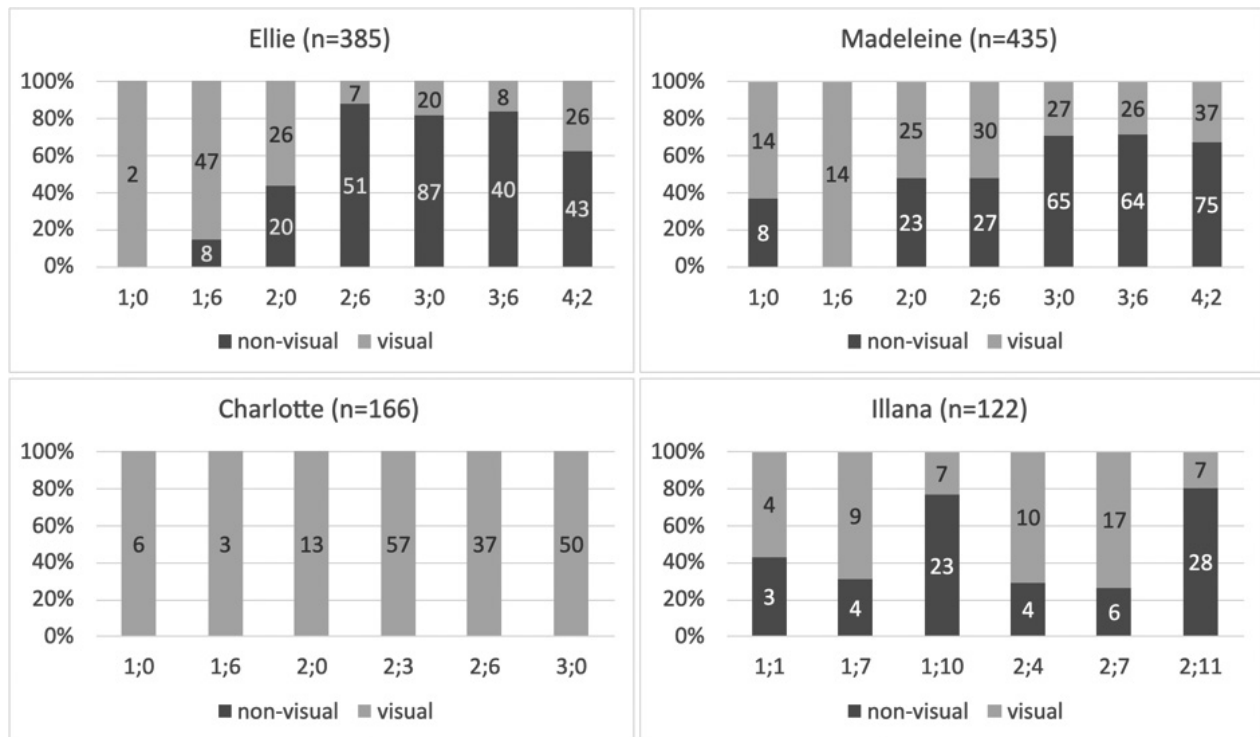


Figure 6. Visual-gestural production (light gray) associated to the symbolic expression of negation in the four children.

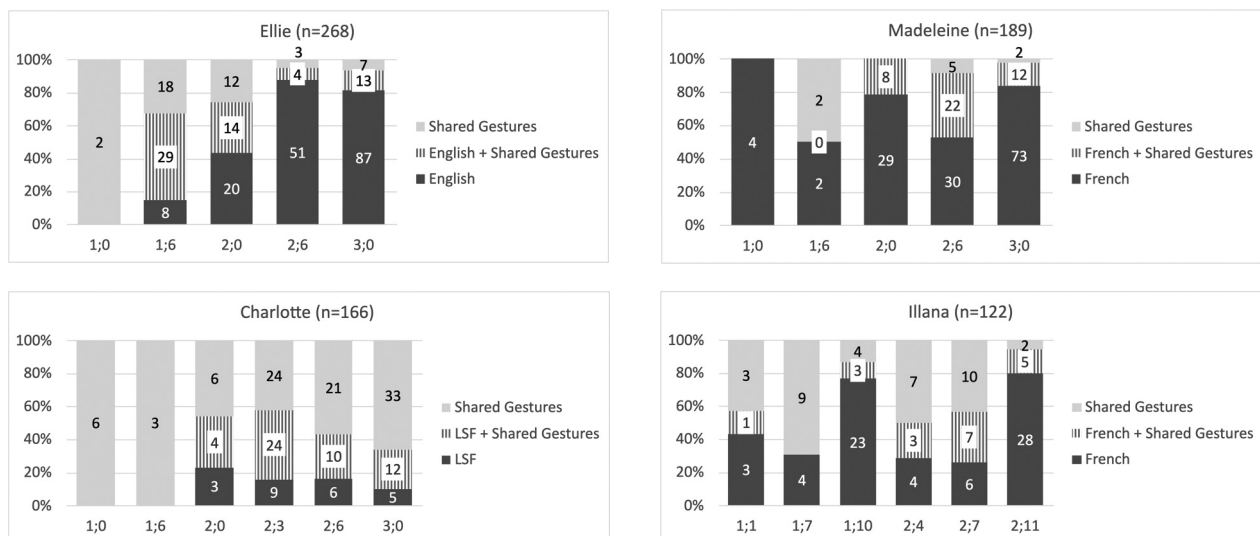


Figure 7. Proportion of Shared Gestures in each of the four children's productions.

Development of negation in the four little girls' productions

We counted all occurrences of what we call *Symbolic* elements (therefore excluding actions and grunts). The proportion of English (in dark gray, Figure 7) and of multimodal productions (in hatching) increases in Ellie's data. From age 1;6, Ellie's multimodal system evolves towards an essentially vocal system with (Shared) Gesture used to complement her vocal productions. We observe the same tendency in the productions of Madeleine who very quickly becomes predominantly vocal (Morgenstern, Blondel, Beaupoil-Hourdel et al., 2017). In

Charlotte (Figure 7), the proportion of Shared Gestures is maintained, and gradually involves the expression of LSF-Specific negation. For Illana, the proportion of Shared Gestures is maintained with the exception of the two sessions in which she speaks almost exclusively to her hearing mother (1;10 and 2;11). When both parents are present, the child uses a higher proportion of Shared Gestures and multimodal productions than Ellie. At the same time, the proportion of LSF-Specific negations is lower and less varied than Charlotte's.

In addition to the balance between visual-gestural and audio-vocal modalities, we observe that the distribution between symbolic categories is conducted differently for each of the children. We will now synthesize the results

of our systematic analysis (see Blondel, Boutet, Beau-poil-Hourdel & Morgenstern, 2017 for a more detailed quantitative account) of the distribution of these forms and how this distribution and its development over time contributes to a more or less systematic grammaticalization of the gestures linked to the expression of negation.

At the beginning of the data, Charlotte mainly produces isolated forms. When she is around 2;0, she starts combining signs. Charlotte's productions of negations become more complex as they progressively include the whole repertoire of forms offered by the visuo-gestural modality both in sequential combinations and in simultaneous combinations. Headshakes precede the emergence of Index-Wagging (Limousin, 2011) and both are at first only copies of her parents' gestures. She experiments with proto-negations, without clear communicative intentions before her productions acquire clearer meaning within the interactional context.

Thus, Charlotte uses signs specific to LSF such as those we can gloss as NONE, NO-MORE as of age 2;0. She first produces Index-Wagging added to bare predicates, then predicative signs with incorporated negation, such as the signs glossed as NOT-KNOW, NOT-WANT which appear between 1;7 and 1;8. Her productions become denser as they combine manual and non-manual elements. Thus, the child sometimes uses Headshakes associated with the negative sign NONE (at 3;0) when it is not mandatory in standard adult use (and she uses the same sign without the Headshake at 2;0). Charlotte also produces formal variants with the same meaning. At 2;3, the child uses both the sign EAT with Index-Wagging (NAME-SIGN EAT Neg-Index ?!, 'Fanny does not eat?!') or with a Headshake (NAME-SIGN EAT Headshake, 'Fanny does not eat'). Instead of replacing one form with another, Charlotte integrates both LSF and Shared Gesture in an increasingly varied linguistic repertoire.

Illana's actions of rejection and non-lexical vocalizations are gradually grammaticalized into combinations of words, signs and Shared Gestures. She continues throughout the recorded sessions to use Headshakes, Index-Wagging and other Shared Gestures, which is clearly characteristic of her bimodal environment. Illana's bimodal production also includes a rich inventory of facial expressions such as squinting, frowning, rounded mouth opening for protest, pouting for disapproval as well as accentuated labialization of the "nan" (for "non" 'no') variant. The evolution of negations in her French productions is different from the other hearing little girls'. As previously indicated, two sessions contain proportionally more negations in French than the other sessions, the forms lengthen and their variety increases. However, the inventory of forms used in the vocal language seems less varied than that of Ellie or Madeleine and some of the structures correspond to what other researchers have called "CODA-talk" (notably Emmorey et al., 2008), namely constructions in French under the influence of LSF syntax. Unlike Charlotte, in Illana's LSF production, there are only a few isolated elements falling within specific LSF negations and there are no occurrences in the data of complex morphology for negation. As she gets

older, she seems to increasingly take advantage of the symbolic combinations of vocal and gestural elements. At the age of 2;2, for example, she combines Headshakes, Index-Wagging and vocal "non". If we consider each of the two languages of the bilingual bimodal little girl separately, and especially if we do not include Shared Gestures, we do not account for the rich semiotic resources of Illana's bimodal repertoire.

If we compare the two little signers, we observe a grammaticalization of their gestures (Pfau, 2002, 2008; Franklin et al., 2011), however Shared Gestures do not disappear in favor of LSF-specific signs. Charlotte uses all the affordances of LSF and Illana exploits the bimodal affordances of her input - Shared Gestures as well as labialization.

In Ellie's early sessions, forms of negation are unconventional and include actions, vocal productions, and combinations of those two semiotic means, while in the last sessions, these unconventional forms have mostly disappeared. The proportion of symbolic gestures is higher at 1;6 and decreases until 2;6 as Ellie engages more and more in the spoken modality. Negations in English are predominant as of 2;0. However, we observe that the raw numbers of gestures continue to increase up to 2;6, which proves that the child's language system is getting richer. As of 2;6 the proportions and the number of productions stabilize. The increase in the proportion of symbolic gestures around 3;0 seems to indicate that as she progressively masters speech, she reintegrates gestures in co-articulation with her vocal productions. Speech and gesture are complementary rather than equivalent. As the vocal modality becomes predominant, Ellie's negative constructions become more complex in English (Beau-poil-Hourdel, Boutet & Morgenstern, 2015). At 3;0, Ellie's negative utterances have a mean average of a little less than 3, which remains relatively high given the number of isolated "no"s produced by the child.

Madeleine expresses her first negations in an unconventional form in more than 80% of cases. As of the age of 1;6, conventional forms take precedence over unconventional forms. Consequently, unconventional productions decrease in proportion and in number in favor of words and symbolic gestures. Just like Ellie, at 3;0, Madeleine's language system is dominated by the vocal modality. The gesture/word combinations she produces are more complex than during the previous months (Beau-poil-Hourdel, 2015) with a decrease in the number of multimodal equivalent combinations (Capirci et al., 1996; Goldin-Meadow & Morford, 1990; Özçalışkan & Goldin-Meadow, 2005).

The two hearing little girls are quite comparable but Madeleine is even more vocal than Ellie earlier on where Ellie engages overall quite productively with the gestural modality.

Distribution of the two contrasted gestural patterns

Within the negation gesture repertoire, we will focus on two of the manual gestures used by children and parents,

both signing and non-signing: Palm-Up and Index-Wagging. What interests us in particular in Index-Wagging, is that signers can either use it in isolation or integrate it into sign language syntax as a negative morpheme, while Palm-Up (and its non-manual declension in shrugs) is used independently from the sign language syntactic flow.

Although these two gestural patterns appear to share the same formal properties in all four children, they are not used to the same extent (as illustrated in Table 4). Thus Madeleine, Ellie, on the one hand, and Charlotte, on the other hand, have contrasting profiles: while the non-signing children use relatively few Index-Wagging gestures (3 gestures over five sessions for Ellie and 4 gestures for Madeleine), the signing child uses them the most (19 gestures over five sessions). Conversely, Madeleine and Ellie use Palm-Up gestures and shrugs more often than Charlotte (26 and 19 for the non-signing children, none for Charlotte in the sessions chosen for our coding): one of the possible explanations is that the signing child has at her disposal other manual gestures to express this type of epistemic negation.

Illana stands between the deaf-signing and non-signing children when it comes to the amount of Index-Wagging gestures coded (8 out of the five sessions), but as we have seen previously, she uses recurrent gestures such as Palm-Up with or without shoulder shrugs the most (26).

Table 4. Distribution of the two gestural patterns among the four children.

Madeleine	Age	1;0	1;6	2;0	2;6	3;0	Total
	PUShrug	0	0	10	8	8	26
	Index	0	0	1	2	0	4
Ellie	Age	1;0	1;6	2;0	2;6	3;0	Total
	PUShrug	0	9	7	2	1	19
	Index	0	1	0	0	2	3
Charlotte	Age	1;0	1;6	2;0	2;6	3;0	Total
	PUShrug	0	0	0	0	0	0
	Index	1	1	2	6	9	19
Illana	Age	1;1	1;7	1;10	2;7	2;11	Total
	PUShrug	0	8	2	14	2	26
	Index	4	0	2	0	2	8

In order to extend this analysis of the two contrasting dynamic gestural patterns, we conducted a more detailed analysis via an exploratory study of Madeleine’s data. We chose Madeleine’s data because she produced very few isolated gestures. Madeleine’s gestures being almost entirely co-verbal, the vocal and gestural modalities were well integrated: gestures co-occurring with vocal negation were therefore likely to also be semantically connected to negation. We thus coded all gestures produced with vocal negations including “non” (‘no’) or “pas” (‘not’).

Meaning and action pattern in Madeleine’s gestures produced with verbal negation

The semantic classification and the kinesiological coding of Shared Gestures produced with “non” and “pas” were done blindly in two separate steps in order to identify the formal cues on which a semantic classification could be based. The results are presented according to the formal features of gestural negation that were identified. First, we explain the invariants of manual negation in terms of *poles*. We then present the semantic and kinesiological coding carried out on Madeleine’s data between the ages of 2;1 and 4;1. We detail the results of our semantic coding and we finally present the results of our coding in *action diagrams*, in connection with the proportion of invariants that the gestures involve for each of the contrastive negative patterns (or poles).

Polar invariants of gestural negation

The polar invariants of gestural negation are distributed over two segmental origins. Negation gestures belonging to the OHP (Open Hand Prone) family are generated on the hand (right part of Figure 8), while negation gestures from the OHS (Open Hand Supine) family originate on

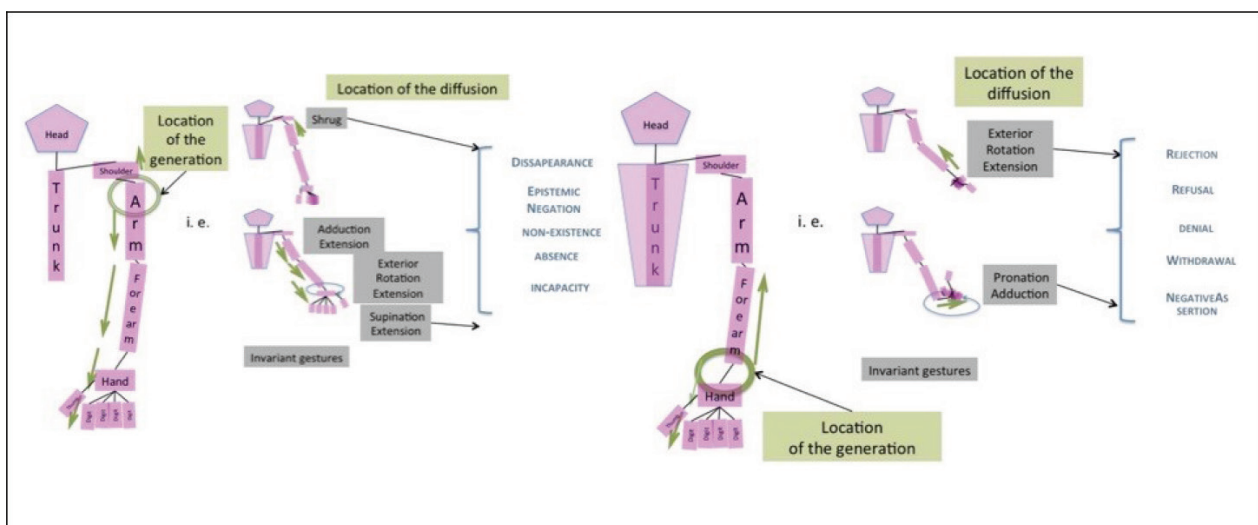


Figure 8. Formal definition of gestural negation features.

the arm (left part of the diagram). The poles of the degrees of freedom at work on each of the original segments are pronation and manual adduction for the first family (OHP) and adduction and extension of the arm, for the second (OHS). Those double movements can be transferred to the forearm according to a distal-proximal flow for the gestures that are generated on the hand (right of Figure 8) and according to a proximal-distal flow for the gestures originating on the arm (left of Figure 8). It turns out that the affected poles on the forearm are the same in both cases: outward rotation and extension of the forearm. As we mentioned earlier, the inertia of the arm prevents the gesture that *originates on the hand* from going up further than the forearm. The *gesture generated on the arm*, however, can be transmitted beyond the forearm, onto the hand, in the form of an extension and a supination.

On the left in the model, the gestures of negation generated on the arm are propagated along the upper limb. That results in a shrug of the shoulder, a movement of adduction and extension of the arm, a movement of external rotation and extension of the forearm and a supination (Palm-Up), and an extension of the hand. On the right, the gestures of negation generated on the hand go upward on part of the upper limb: the results are a pronation movement (Palm-Down or Palm-Forward) and adduction of the hand, an external rotation and an extension of the forearm.

The gestures of negation are generated either at the level of the hand or at the level of the arm. This generation is performed according to two poles each time (Pro. Add for the hand, and Add.Exten for the arm). The first type of gesture diffuses by transferring movement to the fingers on one side and to the forearm on the other. We hypothesize that gestures relating to epistemic negation diffuse towards the shoulder on one side (shrug) and towards the hand on the other according to a proximal-distal flow. All of these diffusions on support segments take place according to particular polar invariants which can be analyzed as poles of negation. Our hypothesis is that *the origin of the movement and its flow can be paired with their semantic value*. When the origin of the movement is on the arm, the gesture expresses absence, incapacity, helplessness, non-existence, disappearance and epistemic negation. When the origin of the movement is on the hand, it expresses rejection, refusal, denial, negative assertion. These formal assumptions relating to the two main families of gestural negation we have presented, apply to Madeleine's productions but also to the other three children's data, as these forms are similar whether they are produced by signers or speakers (see Figures 2 and 4) and display the same invariant poles.

Detailed coding was conducted on Madeleine's data because of the high number of verbal negations and her precocity in producing complex utterances. This involved

identifying and semantically classifying the manual gestures co-occurring with a vocal negation and containing either “non” or “pas”, and coding the poles of the degrees of freedom of the co-occurring gestures.

In our semantic classification we divided gestural occurrences into five categories: 1) actions, 2) refusals or rejections (Neg. Rejection), 3) incapacity, helplessness or epistemic negation (Neg. Epis.), 4) other forms of negation or combinations (Neg. Compo.) and 5) gestures that do not express negation, such as pointing for example.

Our kinesiological coding allowed us to specify the degrees of freedom for four segments (hand, forearm, arm, shoulder). For each of these degrees of freedom, we distinguished position and movement: we noted *the displacement of a segment* which we call *motion* (the hand for example) or a *transfer of movement*. The amplitude was not coded initially⁸ but the intermediate positions (15° on either side of the intermediate position) were coded a posteriori.

Distribution according to semantic criteria

Madeleine performs 930 vocal negations (involving “non” and “pas”) in the sessions coded between the ages of 2;1 and 4;1. Their association with gestures varies with age. The age group between 2;3 and 2;8 involves a higher proportion of symbolic gestures: between 20% and 40% of all negations.

Our semantic coding enabled us to categorize the gestures that overlap the production of “non” or “pas” into four groups. We found no overall significant variation (Fisher test) between the number (48.15%) of gestures of negation (grouping of categories 1 to 3) and the number (51.85%) of gestures expressing something other than negation. On the other hand, the evolution of the four categories according to age is significant (ANOVA, $F(2.75) = 8.46$, $p < 0.00009$). There is therefore an effect of the category on the number of items according to age. The effect of age is also significant among the three types of gestural negation (categories 1, 2 and 3, ANOVA, $F(3.2) = 6.1$, $p < 0.005$).

Thus, our semantic coding indicates that between 2 and 4 years old, gestures expressing negation increase, whereas gestures expressing other functions than negation (pointing for example) are predominant before 2 years old (Guidetti, 2005). Figure 9 illustrates that the proportions of each of these categories change significantly between 2 and 4 years old, which is in line with Choi's observations (1988) on the acquisition of different types of negation in French, Korean and English-speaking children. Beyond this variation according to age, let

8 The changing orientation of the camera in relation to the scene creates visual artifacts which are detrimental to the accuracy of the coding. The other element explaining why we did not code amplitude is the fact that visual cues are generally used to assess the amplitude of a position or a movement. They are based on the distance between the segments of the upper limb and the body, which are quite different for a child's body and change between 2 and 4 years old.

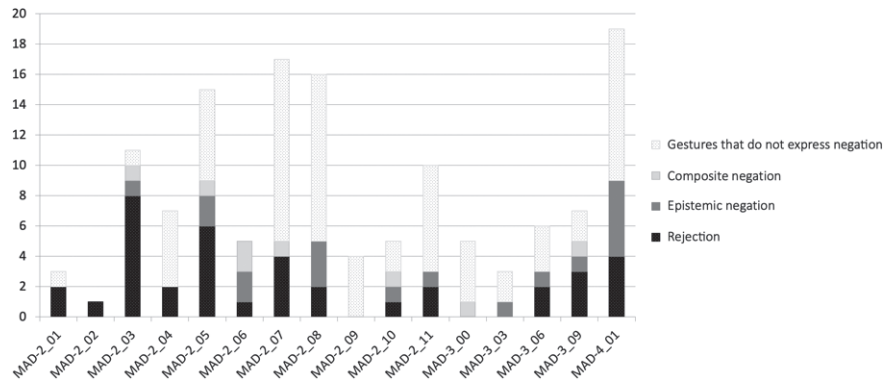




Figure 9. Distribution of symbolic gestures according to semantic type.

Table 4. Polar Invariants: semantic and pragmatic value.

Polar patterns	Index-Wagging (1)	Palm-Up-Shrug (2)
Formal features	Pronation & adduction of the hand	Supination (Palm-Up), and extension of the hand
Semantic Values	Manipulatory, Action on the world, Denial, Refusal...	Interactional, Positioning, Absence, Epistemic negation...
		
Link to videos	https://www.dropbox.com/s/5gyuj18tlw8a2zz/ILL26%20emphatic%20neg.mp4?dl=0 https://www.dropbox.com/s/a2kmm9nk10m9psc/Ellie%20index%20wave.mov?dl=0	https://www.dropbox.com/s/pg3abmdvgurursq/ILL26_palms-up-emph%20%28converti%29.mov?dl=0 https://www.dropbox.com/s/pk8b681na1xwjjz/Ellie%201_05%20palm-up.mov?dl=0

us now look at the formal features that can explain our different labeling of gestures.

Distribution according to formal features

We here synthesize the main formal features of gestures expressing 1) rejection / refusal / denial / negative assertion and 2) epistemic negation / absence / non-existence.

As far as the Rejection category (1) is concerned, hands are in pronation 84% of the time. There is no case of supination. 76.3% are adductions. When the gesture engages the forearm, 78.9% of the time there is an exterior rotation. The transfer of movement onto the forearm is all the easier when the movements of the hand are doubled by a leverage effect as the articular stop is reached. Shrugs are almost inexistent in this category. The gesture is thus mostly distal which is in line with analyses conducted by Calbris (2011).

As far as Epistemic negation (2) is concerned, when hands are engaged, 84.2% are in supination and 64.2% also engage an extension of the hand. There is no manual flexion. We coded an associated shrug in 42% of the cases. The shrug constitutes a sort of breakout for gestures

generated on the arm, as it is a segment with great inertia that can transfer its movement even though it has not reached its maximum amplitude.

Madeleine’s gestures of negation confirm our hypotheses concerning major differences in the distribution of formal features according to semantic categories.

Conclusion

The analyses conducted in this article illustrate how negation is indeed a relevant topic to apply a broad conception of language as a system that integrates a large set of semiotic resources. The manual (or brachial) forms of negation are a good indicator of the structuring and stabilization of gestures. Those expressions of negation are not (visually) *iconic* (in the sense presented in Cuxac, 2000; or Perniss & Viglioco, 2014) for the simple reason that these gestural forms very rarely refer directly to stable referents. Negative signs refer only to themselves. By questioning their structure we can thus try to determine the formal invariants of negation and the semantic features with which each type of form is associated.

The expression of negation stems from a different type of iconicity that we might qualify as form-based, in the sense that gestural forms provide their own semantic value. Following the kinesiological approach, we can thus break down these gestural forms of negation into small articulatory and distinctive units. Instead of presenting movements and positions according to the body's own orientation with an egocentric framework, we describe them according to a series of intrinsic frames of reference centered on each segment (see Morgenstern, Chevrefils, Blondel et al., this issue). By tracking the flow of the gesture as it is deployed along the upper limb segments, our aim is to understand how movement unfolds, and how the formal components of gesture change as it unfolds.

We showed how the four children studied in this paper produced shared gestures combined with the target languages in bimodal expressions of negation. In addition, the two signing children use forms of gestural negation which gradually become grammaticalized and integrated into sign language with age. The other two children evolve in monolingual families speaking French (Madeleine) or English (Ellie). As they are not exposed to sign languages, their gestures of negation evolve differently from those of the two signing children. However, the two signing children have different developmental profiles, which, in addition to individual variations, seem to be linked to the specificity of their interactions with their parents: predominantly monolingual monomodal (Charlotte) versus predominantly bilingual bimodal (Illana). By focusing on two types of shared gestures, Index-Wagging and Palm-Up (associated to Shoulder Shrugs) we have shown that their respective proportions in the data were linked to the role each gesture had in the emergence of a grammar of negation in the target language(s) and modalities.

Beyond the differences in modality and language, we looked for formal invariants linked to gestural negation, as they appeared in the four children's productions. These invariants emerge in two contrasting gestural patterns. The gestural expression of epistemic negation originates on the arm, with a movement of adduction - towards the hips - and extension - towards the back. The other type of gestural negation, around refusal and rejection, originates on the hand and is linked to gripping and manual manipulations (Leroi-Gourhan, 1964). Those gestures are closely related to action on the world. Their common invariants are pronation and adduction.

In our opinion, the shared gestures and specific-SL signs of negation encountered in various corpora and categorized in the literature according to two families (supination and pronation) therefore share formal polar invariants. Specific-SL signs of negation are more conventionalized than Shared Gestures of negation, but both Shared Gestures and Specific-SL signs respect these polar invariants which therefore constitute potential differentiating semantic features of various types of negation. We thus propose a common origin to what are usually called "co-verbal gestures" of negation, and the SL-core lexicon

of negation. This must be tested on larger child datasets in a variety of spoken and sign languages. It could also be extended to the expression of affirmation (as fully complementary to negation). If the analysis of affirmation gestures also brings to light a common formal origin to gestures and signs at the corresponding polar kinesiological level, a system of semantic oppositions could then be coupled with a formal polar opposition system. The systematic study of this overall system would constitute an innovative research avenue. The beginning of a categorial structuring of shared and sign-specific gestures, pairing semantic and formal features, could thus be uncovered. This would confirm that shared gestures and sign-specific gestures are part of a continuum in which semantic and formal features are tightly connected, and that the body *informs* meaning.

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